Proposed Amendment between California Energy Commission
and

DOE- Lawrence Berkeley National Laboratory

Title: Demand Controlled Ventilation: Research for Improving the Specifications in Title 24
Amount: $0.00
Term: 12 months
Contact: Bradley Meister
Committee Meeting: 5/10/2011

Recommendation

Approve this one year, no-cost time extension amendment with Lawrence Berkeley National Laboratory for $0.00. Staff recommends placing this item on the consent calendar of the Commission Business Meeting.

Issue

Because occupancy is highly variable in many buildings, heating and cooling energy consumption can be reduced by modulating ventilation rates in response to actual occupancy, rather than providing the full amount of ventilation needed under conditions of maximum design occupancy. Several studies have estimated the resulting energy savings. Detailed simulation-based analyses for a variety of building types and climates throughout the U.S.indicate that demand control ventilation (DCV) reduces cooling energy up to 20% and that heating energy savings are generally larger. While energy savings has been the primary motivation for use of DCV, this technology can also help to prevent cases of insufficient ventilation, which increase health risks. DCV adds an element of feedback-control into the ventilation delivery process.

Currently, in most buildings there is no real-time or frequent periodic feedback obtained on ventilation rates and consequently, rates are often poorly controlled. Research is needed to better characterize CO2 sensor performance in practice and to provide a basis for modified sensor specifications in Title 24 for CO2. Additionally, there is limited available evidence on whether ventilation rates (VRs) at current guidelines protect health and performance of students (that is, whether VRs above current guideline levels would provide important additional benefits in these areas, or whether VRs even lower than guidelines might already provide optimal benefits); what are the trade-offs between costs and benefits for additional amounts of ventilation; and how does this trade-off change at different VRs (that is, if the costs and/or benefits do not relate linearly with VRs).

The original $870,000 contract was approved in July 2008 to conduct research on the performance of CO2 sensors/transmitters used with DCV, assess potential savings from use of DCV systems in offices, and data collection and evaluation of the effect of lower VRs in schools on student performance and absenteeism. We are requesting a time extension to complete gathering data for an additional year.

For the school ventilation rate project, data collection was hampered by two main problems. First, there was great difficulty recruiting school districts and the final list of participating districts was not determined until later than previously planned and this limited the time period for data collection. For instance, LNBL staff approached 24 districts before getting participation from fewer districts, representing only 110 schools. Second, remote monitoring equipment failures caused some loss of data.

For the 2009-10 school year (September 2009-June 2010), only 110 classrooms were monitored and data collected, for the school year, instead of the planned 180-300 classrooms needed for adequate evaluation and recommendations. The results at this point are inconclusive, and unable to support policy recommendations.

Background

Demand Control Ventilation and CO2 Sensors (Project 1)

DCV systems are designed to automatically modulate the rate of ventilation over time so that adequate rates of ventilation and indoor air quality are maintained, but excessive ventilation and ventilation-related energy consumption are avoided. Minimum ventilation rate standards for many types of spaces include a minimum required ventilation rate per person. Because occupancy is highly variable in many buildings, heating and cooling energy consumption can be reduced by modulating ventilation rates in response to actual occupancy, rather than providing the full amount of ventilation needed under conditions of maximum design occupancy. Several studies have estimated the resulting energy savings. Detailed simulation-based analyses for a variety of building types and climates throughout the U.S. indicate that DCV reduces cooling energy up to 20% and that heating energy savings are generally larger. Modeling for California climate zones found that the combination of DCV and economizer controls was economically attractive for many California climates for office, restaurant, retail, and classroom applications; although, savings were less clearly established in field studies.

While energy savings has been the primary motivation for use of DCV, this technology can also help to prevent cases of insufficient ventilation, which increase health risks. DCV adds an element of feedback-control into the ventilation delivery process. Currently, in most buildings there is no real-time or frequent periodic feedback obtained on ventilation rates and consequently rates are often poorly controlled.

At present, Title 24 requires DCV only for spaces with a large design occupant density (= 25 people per 1000 ft2; classrooms are excluded). Typically, such spaces are meeting rooms, court rooms, assembly areas, and similar rooms with large but discontinuous (sometime infrequent) and variable magnitude occupancy. This type of space represents an ideal application for DCV. Due to the extensive time periods when occupancy is well below the design maximum, the potential energy savings are large.

Almost all current applications of DCV utilize carbon dioxide (CO_2) sensors (sometimes called CO_2 transmitters) to indicate the need for ventilation. Title 24 requires that CO_2 DCV systems maintain indoor CO_2 < 600 ppm above the outdoor concentration and specifies 400 ppm as the default outdoor CO_2 concentration to be used when outdoor CO_2 is not measured. Because the average emission rate of CO_2 from occupants of buildings is reasonably well known, the rate of ventilation per person can be estimated from the equilibrium indoor CO_2 concentration. The elevation of the indoor CO_2 concentration above the outdoor concentration is also an indicator of the indoor concentration of other occupant generated pollutants.

Research has documented the importance of building ventilation rates, and of CO_2 concentrations as indicators of ventilation rates. Prevalence rates of various health symptoms decrease and satisfaction with indoor air quality (IAQ) improves when the ventilation rate per person is higher or the indoor CO_2 concentration is smaller. There is also evidence that rates of common communicable respiratory illnesses and absence rates from work and school are diminished with increased ventilation or lower indoor CO_2. Office work performance also appears to increase when ventilation rates are higher. Thus, there is a reasonable scientific basis for use of DCV systems that maintain minimum ventilation rates or maximum CO_2 concentrations.

CO_2 sensors are a very practical tool for DCV systems because the sensors are widely available at moderate cost. However, the CO_2 sensors used in CO_2 DCV systems must be reasonably accurate; otherwise ventilation rates will not be properly controlled. Title 24 requires "CO_2 sensors shall be factory certified to have an accuracy of no less than 75 ppm over a five year period without recalibration in the field". However, data from our recent pilot survey of CO_2 sensor accuracy (44 sensors in nine California buildings were evaluated) suggests that, in practice, many of the sensors used in CO_2 DCV systems fail to meet this accuracy requirement by a large margin. In single point calibration checks of 37 of the sensors, the average and median of absolute value of errors were 256 ppm and 173 ppm, respectively. As a percent of measured concentration the average and median errors were 68% and 43% respectively. Multipoint calibration checks of 18 of the sensors indicated that many of the sensors had substantial zero offset and/or gain errors. From the multipoint calibration data, predicted errors at 1000 ppm ranged from -994 ppm to +668 ppm and, for half of the sensors, the predicted error at 1000 ppm exceeded 75 ppm. The accuracy of sensors of the same brand was variable and the data were not sufficient data to draw conclusions about the trends in sensor accuracy with sensor age or sensor design. While this pilot study was too small to enable answers many specific questions of interest, the results suggest strongly that many CO_2 DCV systems will fail to adequately control ventilation rates (often by a large margin) without changes in sensor technologies or maintenance and calibration practices. Consequently, the results suggest a need to examine and potentially change specifications for CO_2 DCV in Title 24.

The goal of DCV may be to maintain the ventilation rate per person above some minimum requirement at all times (e.g., above 15 cfm per occupant at all times) or to maintain indoor concentrations of occupant-generated pollutants (CO_2 is an indicator for these pollutants) below the level expected at equilibrium with 15 cubic feet per minute (cfm) per occupant of ventilation. If the sensors are sufficiently accurate, CO_2 DCV is very well suited for meeting the second of these two objectives. As it is normally utilized, CO_2 DCV is not very well suited to meet the first of these objectives (maintaining a minimum ventilation rate per person) because indoor CO_2

concentration changes lag behind changes in occupancy. It may take hours after the start of occupancy before the indoor-outdoor CO_2 concentration difference becomes large enough to be accurately measured even with sensors accurate to within 75 ppm. DCV based on optical occupancy counting systems, as opposed to CO_2 sensors, are an option for meeting this first objective. Optical occupancy counting with suitable algorithms that estimate the lag between entry of occupants and the full buildup in related indoor pollutants may meet the second of these objectives. However, optical occupant counting technologies are new and largely unstudied. One would expect occupancy counting systems, because they rely on discrete counting, to maintain their accuracy over time better than CO_2 sensors, but this has yet to be proven.

The prior discussion highlights several research needs relative to specification of DCV systems in Title 24. For example, research is needed to better characterize CO_2 sensor performance in practice and to provide a basis for modified sensor specifications in Title 24 for CO_2. The potential energy savings from requiring the use of CO_2 DCV in new general office spaces should be considered. Finally, alternatives to the standard practice of using multiple low cost CO_2 sensors in DCV should be evaluated. For example, use of more expensive and stable CO_2 sensors, with multipoint sampling systems to reduce the number of sensors required, and the use of optical occupancy counting systems should be evaluated. The results from this research project will address these areas.

K-12 School Ventilation Rates (Project 2)

Past work in PIER monitored a small number of classrooms that were retrofitted with a new high efficiency Bard heat pump that provided continuous ventilation. This new work with LBNL will be coordinated with input from this past project that used a similar method of collecting data.

There is limited available evidence on whether ventilation rates (VRs) at current guidelines protect health and performance of students (that is, whether VRs above current guideline levels would provide important additional benefits in these areas, or whether VRs even lower than guidelines might already provide optimal benefits); what are the trade-offs between costs and benefits for additional amounts of ventilation; and how does this trade-off change at different VRs (that is, if the costs and/or benefits do not relate linearly with VRs).

A number of studies (e.g., (Erdmann and Apte 2004)) and reviews (Seppanen et al. 1999; Wargocki et al. 2002) have investigated the relationship between ventilation rates and health outcomes (respiratory disease, sick building syndrome symptoms), and absence rates; however, most studies have been performed in office buildings. Some studies have used indoor CO_2 concentrations as a surrogate for ventilation rate per occupant. A large majority of these studies have found a worsening of some health or absence outcome at lower ventilation rates. Studies show consistently that as ventilation rates increase within the range below 20 cfm per occupant, significant health benefits are consistently apparent. Some but not all studies also report additional benefits of increasing ventilation rates even above 20 cfm per occupant. Sufficient research is not available, even in office buildings from which most such research is available, to settle the question of the magnitude of benefits from raising VRs above 20 cfm/person. Because classrooms differ from office buildings in occupant density, average age of occupant, and types of indoor pollutant sources, additional data from schools is necessary. The results from this research project will address these areas and correlate with student absenteeism and performance.

Proposed Work

Project 1: The goal of this research is to develop the information needed to evaluate and, as necessary, suggest revised specifications in the Commission's Title 24 standards pertaining to Demand Controlled Ventilation (DCV), to improve our understanding of the in-situ performance of CO_2 sensors/transmitters used with DCV systems and to determine causes of large CO_2 measurement errors. Additionally, we will assess potential energy savings in California from use of DCV systems in general office spaces.

Project 2: This research will study public classrooms in school districts within a range of California climate zones. It will include 180-300 classroom-years of data collected over three school years. Sensors in each classroom will collect real-time classroom data on CO_2, temperature, and humidity that can be easily retrieved remotely. Data on student absence and attendance will be collected.

Benefits of extending study by one year:

The Energy Commission is funding 80% of total effort and US Green Building Council is funding 20%. The money from the US Green Building Council is paying for the additional year-long study of test scores.

Major expansion of current data set from 110 to 250 classroom years, at no increased cost

Extension offers an extremely cost-efficient way to increase study size and power

Major initial expense and effort of district and school selection, purchase and installation of monitors, and arrangement of data from schools already completed.

Future environmental data collection, through web-connected sensors from 150 California classrooms, is at no cost to the Commission.

Because technical issues are resolved, additional data collection from the current school year will more than double available data, substantially increase power of the analyses, and allow more conclusive findings.

Justification and Goals

This project "[will develop, and help bring to market] increased energy efficiency in buildings, appliances, lighting, and other applications beyond applicable standards, and that benefit electric utility customers" (Public Resources Code 25620.1.(b)(2)), (Chapter 512, Statues of 2006)).

This will be accomplished by:

Increased energy efficiency in buildings per SB1250 and to develop an aggressive implementation plan for improving the energy efficiency of existing buildings as a follow-up to its AB 549 report per the Integrated Energy Policy Report 2005 by:

- Maximizing the benefits of electricity use for ventilation
- Improving building performance and reducing grid-based electrical energy purchases in commercial buildings